Astrophysics1 *[138 marks]*

1a. *[1 mark]*

Markscheme

a galaxy is much larger in size than a solar system

a galaxy contains more than one star system / solar system

a galaxy is more luminous

Any other valid statement.

[1 mark]

1b. *[1 mark]*

Markscheme

a comet is a small icy body whereas a planet is mostly made of rock or gas

a comet is often accompanied by a tail/coma whereas a planet is not

comets (generally) have larger orbits than planets

a planet must have cleared other objects out of the way in its orbital neighbourhood

[1 mark]

2a. *[1 mark]*

Markscheme

stars fusing hydrogen «into helium»

[1 mark]

2b. *[1 mark]*

Markscheme

$M = M_{\odot}\left(4 \times 10^{5}\right)^{\frac{1}{3.5}} = 39.86 M_{\odot}$

«$M \approx 40 M_{\odot}$»

Accept reverse working.

[1 mark]

2c. *[2 marks]*

Markscheme

$4 \times 10^5 = 13^2 \times \frac{T^4}{6000^4}$

$T \approx 42\,000$ «K»

Accept use of substituted values into $L = \sigma 4 \pi R^2 T^4$.

Award ***[2]*** *for a bald correct answer.*

[2 marks]

2d. *[2 marks]*

Markscheme

$4 \times 10^{-11} = 4 \times 10^5 \times \frac{1\text{AU}^2}{d^2}$

$d = 1 \times 10^8$ «AU»

Accept use of correct values into $b = \frac{L}{4\pi d^2}$.

[2 marks]

2e. *[2 marks]*

Markscheme

the gravitation «pressure» is balanced by radiation «pressure»

that is created by the production of energy due to fusion in the core / OWTTE

Award ***[1 max]*** *if pressure and force is inappropriately mixed in the answer.*

Award ***[1 max]*** *for unexplained "hydrostatic equilibrium is reached".*

[2 marks]

2f. *[3 marks]*

Markscheme

the Sun will evolve to become a red giant whereas Theta 1 Orionis will become a red super giant

the Sun will explode as a planetary nebula whereas Theta 1 Orionis will explode as a supernova

the Sun will end up as a white dwarf whereas Theta 1 Orionis as a neutron star/black hole

[3 marks]

3a. *[1 mark]*

Markscheme

two stars orbiting about a common centre «of mass/gravity»
Do not accept two stars orbiting each other.

3b. *[4 marks]*

Markscheme

i
stars are roughly at the same distance from Earth
OR
d is constant for binaries

$\frac{L_{\mathrm{A}}}{L_{\mathrm{B}}} = \frac{1.5}{0.5} = 3.0$

Award **[2]** for a bald correct answer.

ii

$r = \sqrt{\frac{1.5 \times 3.8 \times 10^{26}}{5.67 \times 10^{-8} \times 4\pi \times 5800^4}}$

= 8.4 × 10^8 «m»

*Award **[2]** for a bald correct answer.*

3c. *[2 marks]*

Markscheme

«A=$\frac{L}{\sigma T^4}$» B and A have similar temperatures

so areas are in ratio of luminosities

«so B radius is less than A»

3d. *[3 marks]*

Markscheme

radiation pressure/force outwards

gravitational pressure/force inwards

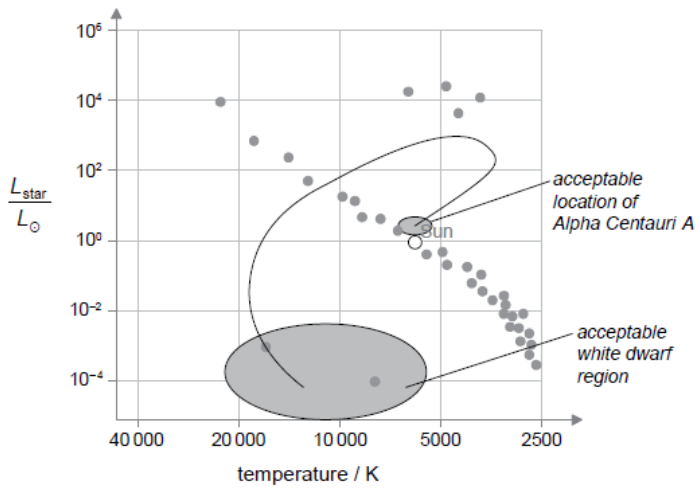
forces/pressures balance

3e. *[2 marks]*

Markscheme

Alpha Centauri A within allowable region

some indication of star moving right and up then left and down ending in white dwarf region as indicated



4a. *[1 mark]*

Markscheme

made of dust and/or gas
formed from supernova
can form new stars
some radiate light from enclosed stars
some absorb light from distant stars

4b. *[2 marks]*

Markscheme

$d = \frac{1}{8.32\times10^{-3}}$ ***OR*** 120pc

$120\times3.26\times9.46\times10^{15}=3.70\times10^{18}$m

Answer must be in metres, watch for POT.

4c. *[1 mark]*

Markscheme

distances are so big/large ***OR*** to avoid using large powers of 10 ***OR*** they are based on convenient definitions

5a. *[2 marks]*

Markscheme

$T = \frac{2.9\times10^{-3}}{740\times10^{-9}}$

3900 K

Answer must be to at least 2SF.

5b. *[2 marks]*

Markscheme

L=5.67×10^{-8}×4π×(3.1×10^{10})^2×4000^4

=1.8×10^{29}W

Accept use of 3900^4 to give 1.6×10^{29}W.

5c. *[2 marks]*

Markscheme

absorption lines in spectra

are specific to particular elements

Accept "emission lines in spectra".

5d. *[1 mark]*

Markscheme

helium

5e. *[3 marks]*

Markscheme

helium flash
expansion of outer shell ***OR*** surface temperature increase
planetary nebula phase
only the core remains
if below 1.4M_S/Chandrasekhar limit then white dwarf

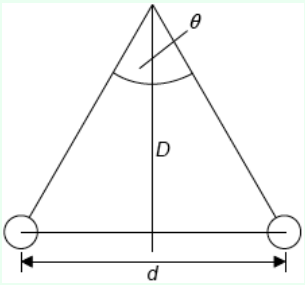
6a. *[1 mark]*

Markscheme

the star is (much) closer than the other star (and close enough to Earth) / parallax effect has been observed;

6b. *[1 mark]*

Markscheme



*Award **[1]** if all three (d, D, θ) are shown correctly.*

Do not allow d shown as the radius.

Accept D as a line from Earth to the star.

6c. *[2 marks]*

Markscheme

$\sin\frac{\theta}{2}=\frac{d}{2D}$ ***or*** $\tan\frac{\theta}{2}=\frac{d}{2D}$ ***or*** $\theta=\frac{d}{D}$;

consistent explanation, *eg*: small angle of approximation yields $\theta=\frac{d}{D}$;

Allow ECF from (b)(i), eg: if d shown as radius.

6d. *[1 mark]*

Markscheme

any angular unit quoted for θ and any linear unit quoted for D;

6e. *[1 mark]*

Markscheme

(yes) star is close enough (in local galaxy) to determine spectral characteristics;

***Note**: not the same question as HL.*

7a. *[3 marks]*

Markscheme

$\frac{L_{\mathrm{V}}}{L_{\mathrm{S}}} = \left(\frac{\sigma A_{\mathrm{V}} [T_{\mathrm{V}}]^4}{\sigma A_{\mathrm{S}} [T_{\mathrm{S}}]^4} = \right) \frac{\sigma [r_{\mathrm{V}}]^2 [T_{\mathrm{V}}]^4}{\sigma [r_{\mathrm{S}}]^2 [T_{\mathrm{S}}]^4}$;

$\frac{1.54 \times 10^{28}}{3.85 \times 10^{26}} = \frac{[r_{\mathrm{V}}]^2}{[r_S]^2} \times \frac{9600^4}{5800^4}$;

$r_{\mathrm{V}} = \left(\sqrt{\frac{1.54 \times 10^{28}}{3.85 \times 10^{26}} \times \frac{5800^4}{9600^4}} r_S = \right) \ 2.3 \ r_{\mathrm{S}}$;

Do not award third marking point if radius of the Sun is lost.

7b. *[3 marks]*

Markscheme

obtain the spectrum of the star;

measure the position of the wavelength corresponding to maximum intensity;

use Wien's law (to determine temperature); } *(allow quotation of Wien's equation if symbols defined)*

*Award **[3 max]** for referring to identification of temperature via different ionizations of different elements.*

8a. *[4 marks]*

Markscheme

(i) $T = \frac{0.0029}{\lambda}$;
3080/3090 (K); *(more than 1 SD must be shown)*

(ii) temperature too low for white dwarf;
not luminous enough for red giant;

8b. *[8 marks]*

Markscheme

(i) $L = 4\pi d^2 b$;
$\frac{d_B}{d_S}\left(= \sqrt{\frac{L_B}{L_S}\frac{b_S}{b_B}}\right) = \sqrt{\frac{3.8\times10^{-3}}{2.5\times10^{-14}}}$;
3.9×10^5 AU;

(ii) conversion of AU to 1.89 pc;
0.53 (arc-seconds);

(iii) measure position of star;
with respect to fixed background;
with six months between readings;
parallax angle is half the total angle / *OWTTE*;
May be shown in a diagram.

9a. *[3 marks]*

Markscheme

A: white dwarf;

B: main sequence / blue giant / blue supergiant;

C: red giant / red supergiant;

9b. *[4 marks]*

Markscheme

(i) *apparent brightness:* (total) power received per unit area/per m^2} *(accept luminosity for power)*
luminosity: (total) power radiated;
Accept energy per second instead of power.

(ii) $d = \sqrt{\frac{L}{4\pi b}}\left(= \sqrt{\frac{10^4\times3.9\times10^{26}}{4\pi\times3.8\times10^{-10}}}\right)$; *(mark is for rearrangement)*
d=2.9 $\times$ 1019 (m);
*Award **[1]** for 2.9×1017 (misses factor of 10000).*
*Award **[2]** for a bald correct answer.*

9c. *[2 marks]*

Markscheme

same shape as curve in graph and displaced to right;
peak at 10 ± 2 $\times$ 10-7 m with intensity ≤1;

10. *[2 marks]*

Markscheme

stars of stellar clusters are close together (in space)/bounded gravitationally;

stars of constellations are not bounded gravitationally/appear to be close together (from Earth);

11. *[2 marks]*

Markscheme

the position of the star (relative to the fixed background) is measured six months apart/January to July;

the parallax angle p can be used to determine the distance using $d = \frac{1}{p}$;

12. *[2 marks]*

Markscheme

icy/dusty object;
moving around the Sun on a (highly) elliptical orbit;
when close to Sun likely to display atmosphere (coma)/tail;
when far from Sun (ice re-freezes and) atmosphere no longer present;

*Award **[2]** only if it is clearly stated that the object is a part of a Solar system.*

13a. *[2 marks]*

Markscheme

(i) stars, and not planets, have cores undergoing fusion;

stars have much greater mass/luminosity/absolute magnitude/temperature than planets;

planets reflect starlight rather than emit;

planets in our solar system can show retrograde motion, stars cannot;

Allow other sensible answers.

(ii) stars in a stellar cluster are close to each other/kept together by gravitation, the stars in a constellation are not;

13b. *[2 marks]*

Markscheme

(i) the lines in the (absorption) spectrum of the star (correspond to hydrogen wavelengths);

(ii) the gravitational force that tends to collapse the star is balanced by a force due to radiation pressure;

13c. *[2 marks]*

Markscheme

peak wavelength is at 400 (nm); *(accept answers in the range of 380 to 420 (nm))*

$T = \left(\frac{2.9\times10^{-3}}{400\times10^{-9}} =\right)\ 7250\ (\text{K})$; *(accept answers in the range of 6900 to 7600 (K))*

*Award **[2]** for a bald correct answer.*

14a. *[2 marks]*

Markscheme

$L\left(= 4\pi bd^2\right) = 4 \times \pi \times 1.2 \times 10^{-7} \times \left[8.1 \times 10^{16}\right]^2$;

9.9×10^{27}(W);

Allow 1.3×10^{28}(W) if candidates use 3 (pc) from (a).

14b. *[2 marks]*

Markscheme

$\frac{\text{M}_{\text{Sirius}}}{\text{M}_{\text{Sun}}}\left(= \left[\frac{\text{L}_{\text{Sirius}}}{\text{L}_{\text{Sun}}}\right]^{\frac{1}{3.5}}\right) = \left[\frac{9.9\times10^{27}}{3.8\times10^{26}}\right]^{\frac{1}{3.5}}$;

$\text{M}_{\text{Sirius}} = 2.5\text{M}_{\text{Sun}}$;

Allow ECF from (b).

15a. *[2 marks]*

Markscheme

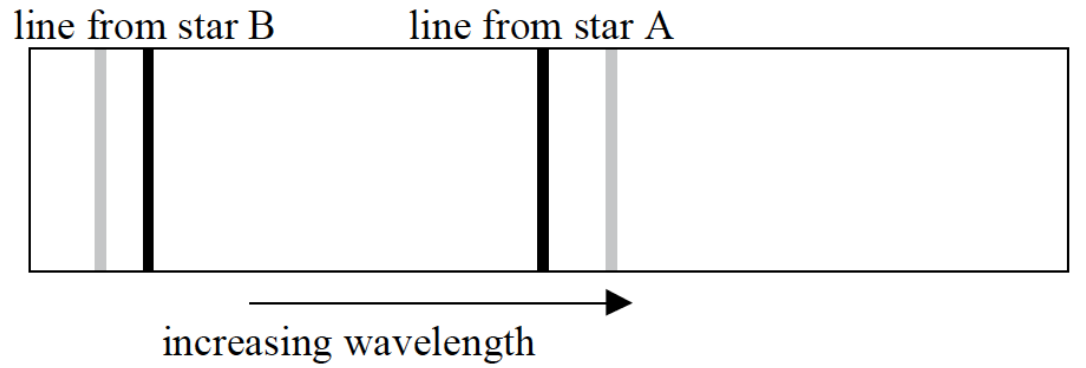
$\frac{L_{\text{A}}}{L_{\text{B}}} = \frac{\sigma 4\pi R_{\text{A}}^2 T_{\text{A}}^4}{\sigma 4\pi R_{\text{B}}^2 T_{\text{B}}^4}$;

$\frac{L_{\text{A}}}{L_{\text{B}}} = 0.60^4 \times 270^2$ ***or*** look for 3 or more sig fig *eg* 9.45×10^3;

$\left(\frac{L_{\text{A}}}{L_{\text{B}}} = 9.4 \times 10^3\right)$

15b. *[2 marks]*

Markscheme

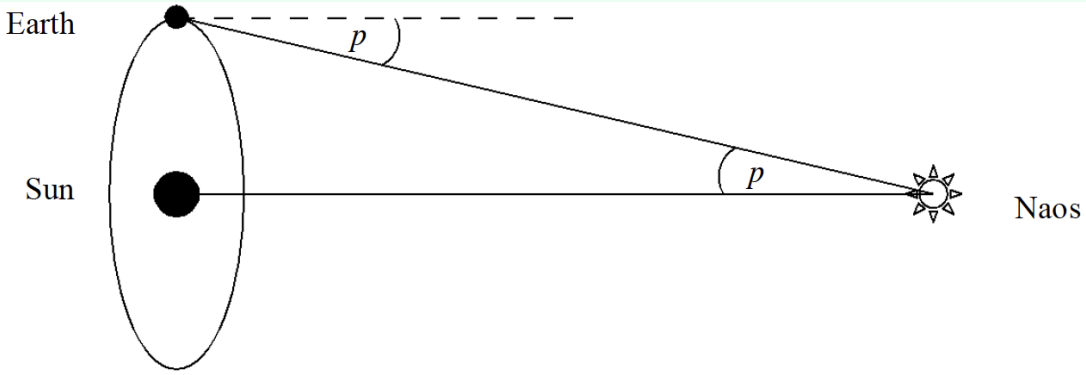


*Award **[1]** for each correct line.*
The shifted lines are light grey in the diagram above. Ignore magnitude of shift.
*Award **[0]** if more than two lines are drawn unless it is clear which lines are to be marked.*

16. *[3 marks]*

Markscheme

(i) either angle *p* as shown;



(ii) the star's position is observed at two times, six months apart;
the shift in the star's position relative to the distant stars is (twice) the parallax angle;

Accept correct answers which are clear from annotations on the diagram.

17a. *[7 marks]*

Markscheme

(i) a constellation is a collection of stars that form a (recognizable) pattern (as viewed from Earth);
the distances between the stars may be very large;
a stellar cluster is a group of stars held together by (mutual) gravitational attraction/gravity/are physically relatively close;
there can be many thousands of stars in the cluster;
all stars in the cluster were created about the same time;

(ii) the (total) power radiated/emitted/produced (by the star);

(iii) luminosity of Aldebaran = $370\times3.9\times10^{26}=1.44\times10^{29}$ W;
$= \sqrt{\frac{1.44\times10^{29}}{4\pi\times3.3\times10^{-8}}} = 5.9\times10^{17}$;
$= \frac{5.9\times10^{17}}{3.1\times10^{16}} = 19\text{pc}$;

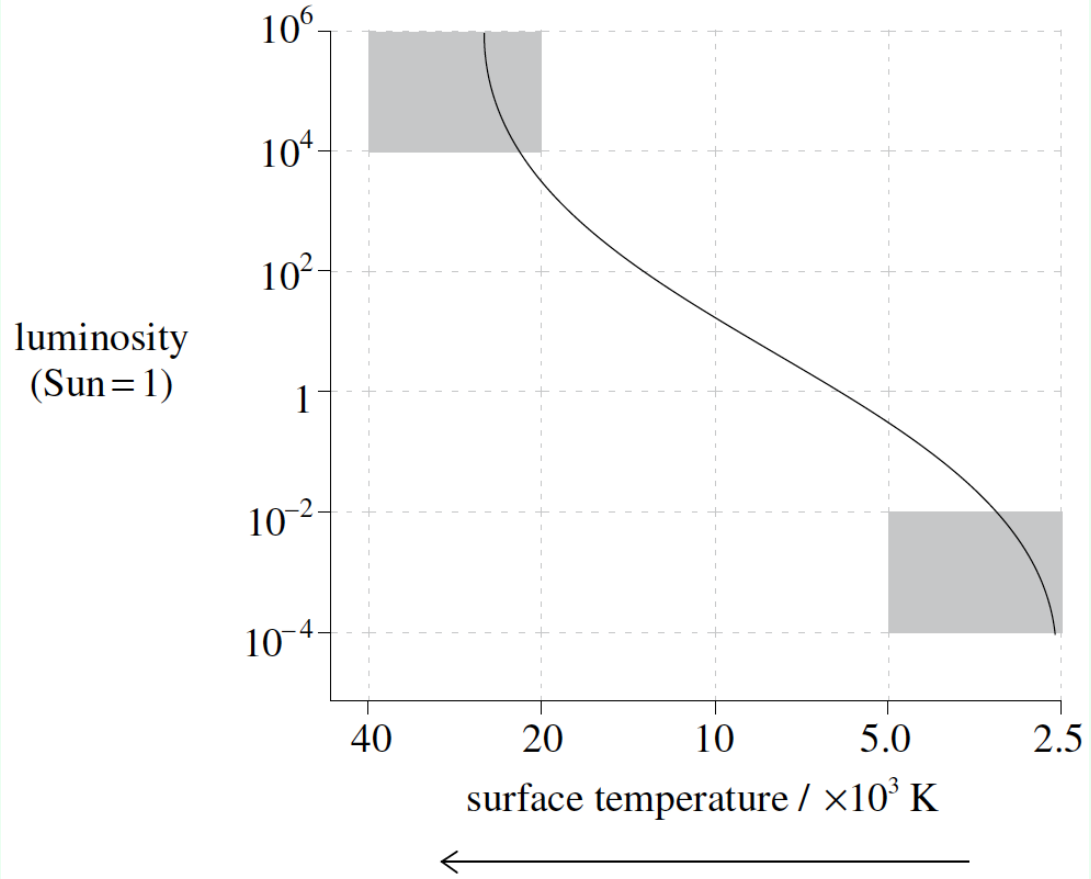
17b. *[5 marks]*

Markscheme

the (outer layers of the star) undergo a (periodic) expansion and contraction;
which produces a (periodic) variation in its luminosity/apparent brightness;
the (average) luminosity depends on the period of variation;
by measuring the period, the luminosity can be found;
by then measuring its apparent brightness, its distance from Earth can be found;

18a. *[2 marks]*

Markscheme



any suitable line from anywhere in top left-hand quadrant; *(accept a straight line)*
to bottom right-hand quadrant;
The shaded areas are the limits within which the line must be drawn.

18b. *[2 marks]*

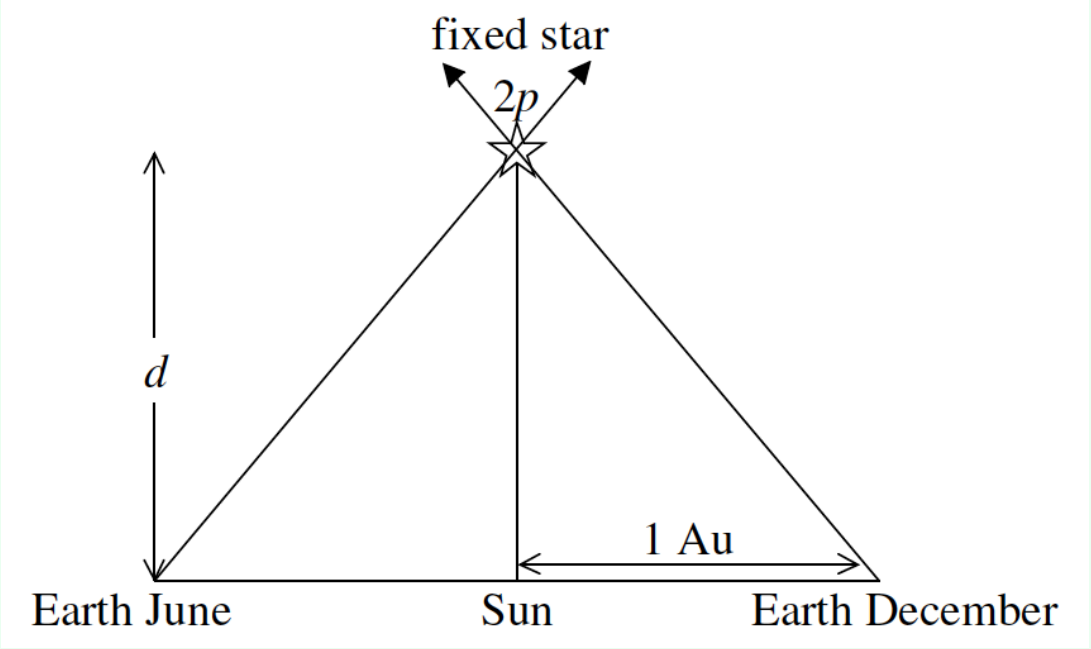
Markscheme

(i) distance at which 1 AU subtends an angle of 1 arcsec / distance at which the angle subtended by the radius of Earth's orbit is 1 arcsec;

(ii) $p = \left(\frac{1}{d} =\right) 0.56\text{arcsec};$

18c. *[3 marks]*

Markscheme



Labelled diagram should relate to the following points:
measure against the fixed stars the angle Barnard's star subtends at Earth in June and again in December;
difference between the two angles is twice the parallax angle;
orbital radius of Earth about Sun is 1 AU so distance to star is computed from $d = \frac{1}{p}$;

18d. *[6 marks]*

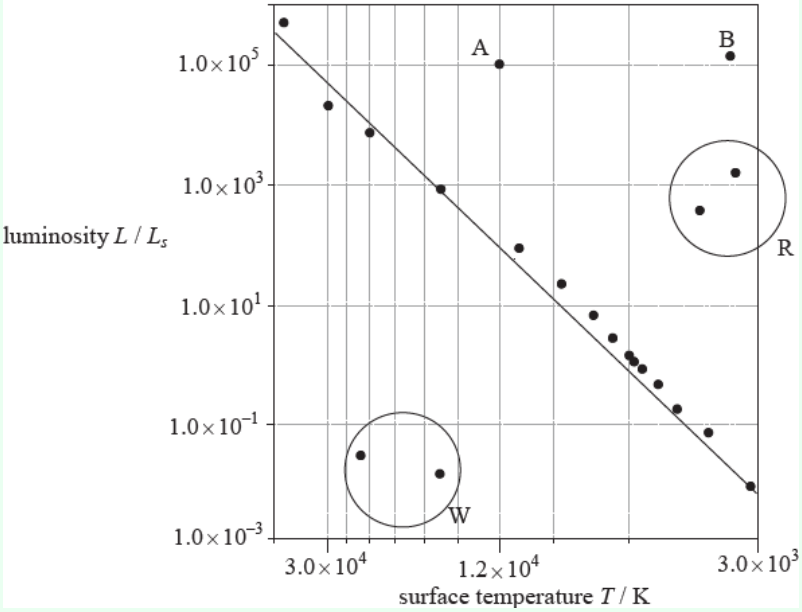
Markscheme

(i) $L=4\pi bd^2$;
$=4\times3.14\times3.6\times10^{-12}\times[1.8\times3.1]^2\times10^{32}$;
$=1.4\times10^{23}$W;
$\approx10^{23}$W

(ii) $A = \frac{L}{\sigma T^4}$;
$= \frac{1.4\times10^{23}}{5.67\times10^{-8}\times3.8^4\times10^{12}}$; *(allow ECF from (d)(i))*
$=1.184\times10^{16}$m^2;
$\approx10^{16}$m^2

19a. *[3 marks]*

Markscheme



(i) circle labelled R as shown above;
Accept answers that include the star B within the circle.

(ii) circle labelled W as shown above;

(iii) any line (not necessarily straight) going from top left to bottom right, through or near all or most of stars;

19b. *[3 marks]*

Markscheme

star B has lower temperature;
star B has (slightly) larger luminosity / stars have approximately same luminosity;
surface area calculated from $L=\sigma AT^4$, so star B has larger surface area/diameter / to give the same/similar luminosity at lower temperature, star B must have bigger diameter/surface area;

19c. *[4 marks]*

Markscheme

(from HR diagram) $L_A = 10^5 L_S$;
$b = \frac{L}{4\pi d^2}$ used;
to give $\frac{d_A}{d_S} = \sqrt{\frac{L_A}{L_S} \times \frac{b_S}{b_A}} = \sqrt{10^5 \times \frac{1.4\times10^{3}}{4.9\times10^{-9}}}$;
hence $d_A = 1.7\times10^8$ AU;
= 800 pc
Do not award a mark for the conversion from AU to pc.

19d. *[1 mark]*

Markscheme

the parallax angle is too small to be measured accurately / the distance is greater than the limit for stellar parallax, which is 100 pc;
Accept any value from 100–800 pc for limit. Do not accept "it's too far away".

20a. *[3 marks]*

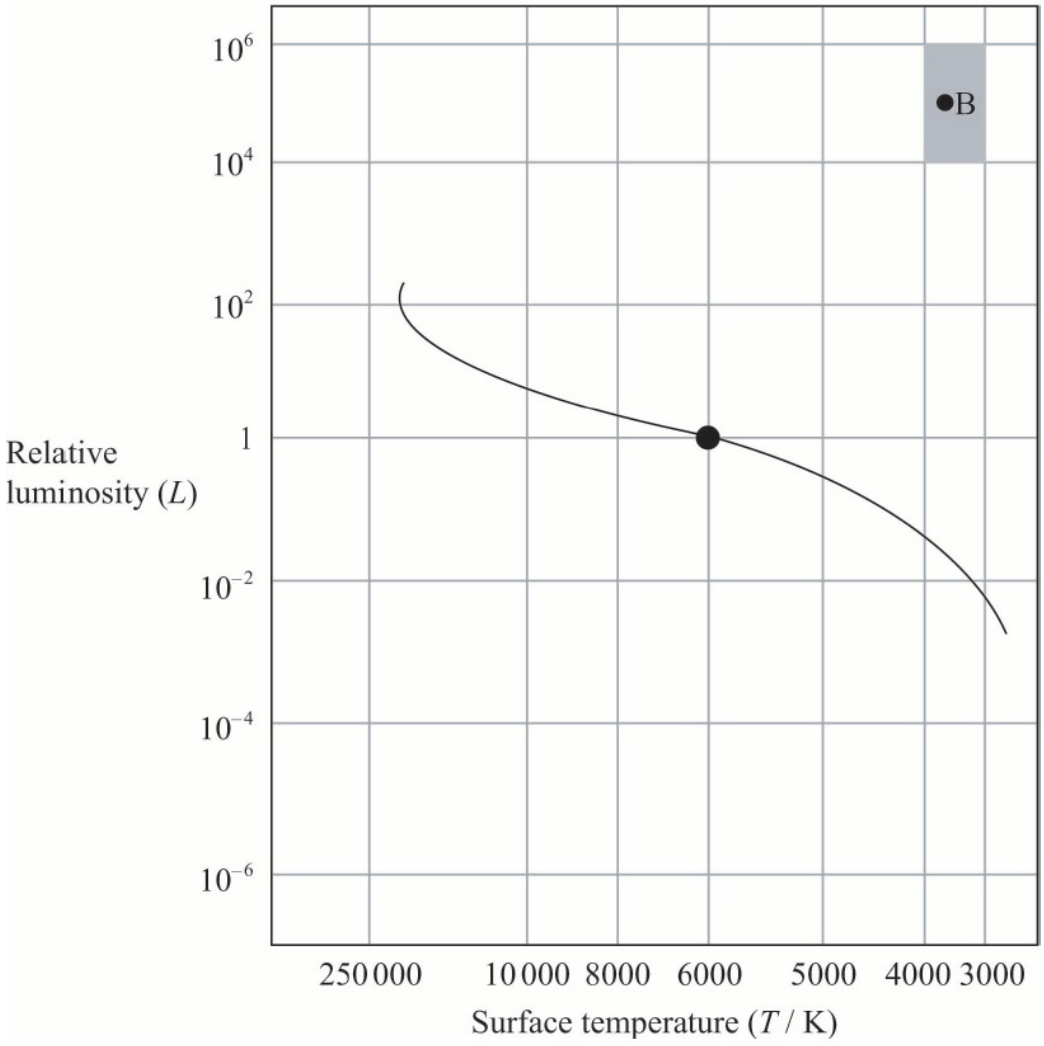
Markscheme

(i) a collection of stars that form a recognizable group (as viewed from Earth);
that need not be/are not close to each other/gravitationally bound;

(ii) stars that are gravitationally bound/forming an open arrangement/close to each other (in space);

20b. *[2 marks]*

Markscheme



(i) position labelled B within shaded area;
*Award **[1]** if label B is missing but point is clear.*

(ii) generally the correct shape; *(allow broad line)*

21. *[2 marks]*

Markscheme

constellation:

a collection/group of stars that form a recognizable pattern (as viewed from Earth) / a group/pattern of stars not close together (in space);

stellar cluster:

a group of stars (including gas and dust) held together by gravity/forming a globular/open arrangement / a group of stars close to each other (in space);

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